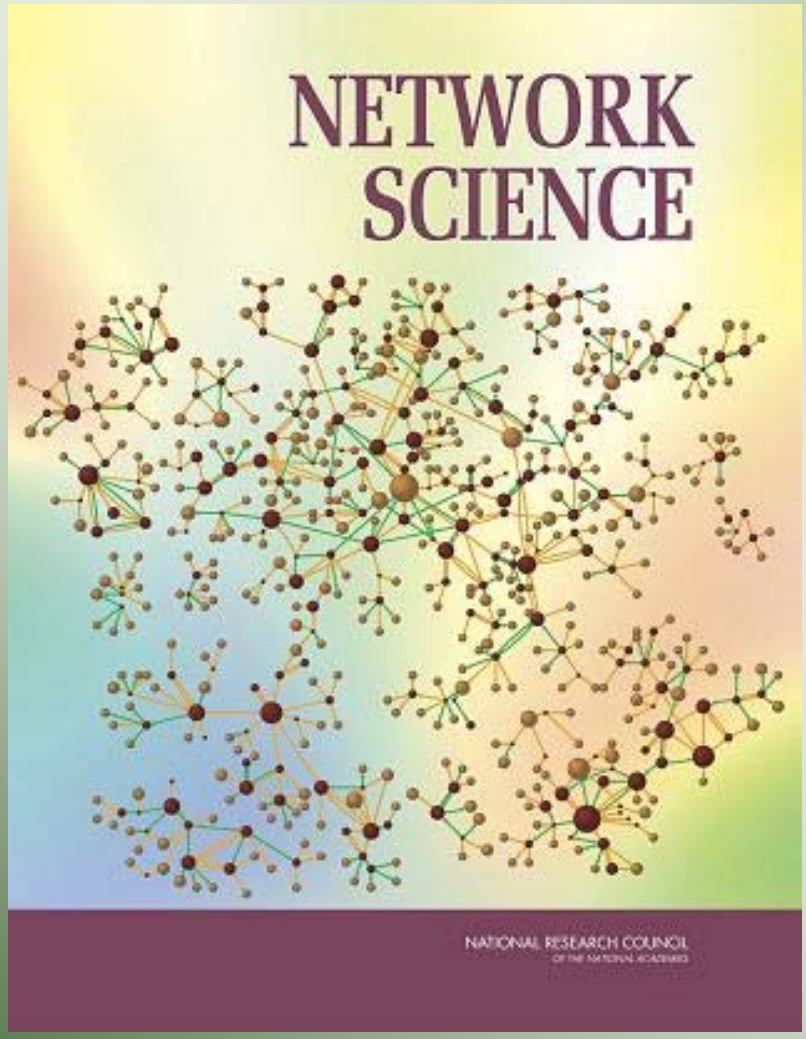

2006 Army Science Conference
Panel on Network Science

Presented by
Dr. Will Leland
Panel Subcommittee Chair

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THE NATIONAL ACADEMIES
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National Research Council
Committee on Network Science for Future Army Applications

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Overview

- A committee of technical experts, military officers and R&D managers was assembled by the National Research Council to reach consensus on the nature of networks and network research
- It evaluated extensive data collected from the literature and from a large, diverse sample of active network researchers
- The data were analyzed to provide both general learning on networks and answers to specific questions about a field of Network Science as posed by the statement of task
- The resulting report was published in 2005 and describes a context, scope, content, and challenges for Network Science as a coherent field of investigation for the Army

Study Team

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Consultant
(net-centric warfare applications)

Dr. Duncan Watts
Columbia University
(sociology)

What It Accomplished

- Reviewed literature on engineered (physical), biological, and social networks and on systems theory to determine the scope of network science
- Conducted telephone interviews and distributed e-mail questionnaires to over 1000 active participants in network research to sample opinions on coherency of network science as a field of investigation
- Surveyed academic courses to describe current content of network science
- Analyzed questionnaire responses to identify common challenges in network science
- Synthesized data to answer questions posed by the statement of task
- Constructed scenarios to illustrate the prospective value of network science research to the Army

Study Findings: The Big Picture

- Networks are pervasive in all aspects of life: biological, physical and social. They are indispensable to the workings of the global economy and the defense of the United States.
- Fundamental knowledge needed to predict the properties of large infrastructure networks is primitive, notwithstanding the advanced technological state of global communications and transportation networks. There is no science today that offers the fundamental knowledge necessary to design large, complex networks in such a way that their behaviors can be predicted prior to building them.
- Research on networks is fragmented. Current funding policies and practices of federal agencies are focused on specific network applications rather than on accumulating fundamental knowledge about networks.

Study Findings:
Should a Field Called Network Science Exist?

- **Task:** Determine whether initiation of a new field of investigation called Network Science would be appropriate to advance knowledge of complex systems and processes that exhibit network behaviors. If yes, how should it be defined?
- **Response:** Initiation of a field of network science would be appropriate to provide a body of rigorous results that would improve the predictability of the engineering design of complex networks and also speed up basic research in a variety of applications areas.

  A working definition of network science is the study of network representations of physical, biological, and social phenomena leading to predictive models of these phenomena.

Study Findings: Content and Challenges

- **Task:** Identify the fields that should comprise Network Science. What are the key research challenges necessary to enable progress in Network Science?
- **Response:** General consensus existed among practitioners of network research in diverse application areas on topics that comprise network science. Practitioners identified seven major network science research challenges.

Research Challenges

- ***Dynamics, spatial location, and information propagation in networks.*** **Better understanding of the relationship between the architecture of a network and its function is needed.**
- ***Modeling and analysis of very large networks.*** **Tools, abstractions, and approximations are needed that allow reasoning about large-scale networks, as well as techniques for modeling networks characterized by noisy and incomplete data.**
- ***Design and synthesis of networks.*** **Techniques are needed to design or modify a network to obtain desired properties.**
- ***Increasing the level of rigor and mathematical structure.*** **Many of the respondents to the questionnaire felt that the current state of the art in network science did not have an appropriately rigorous mathematical basis.**
- ***Abstracting common concepts across fields.*** **The disparate disciplines need common concepts defined across network science.**
- ***Better experiments and measurements of network structure.*** **Current data sets on large-scale networks tend to be sparse, and tools for investigating their structure and function are limited.**
- ***Robustness and security of networks.*** **Finally, there is a clear need to better understand and design networked systems that are both robust to variations in the components (including localized failures) and secure against hostile intent.**

Study Findings: Research Issues and Practical Challenges

- **Task:** Identify specific research issues and the theoretical, experimental, and practical challenges to advance the field of Network Science. Consider such things as facilities and equipment that might be needed. Determine investment priority, time frame for realization, and degree of commercial interest.
- **Response:**
  - The report lists current areas of network research of interest to the Army, including priority, time frames, and commercial interest
  - Current funding policies and priorities are unlikely to provide adequate fundamental knowledge about large complex networks that will advance network-centric operations
  - The basis for network science is perceived in different ways by the communities concerned with engineered, biological, and social networks. Basic research efforts in these areas are incoherent
  - Options for obtaining value from investments in network science range from building a base of basic research, to leveraging business practices for "market-driven" R&D in network applications, to creating a robust capability for network-centric operations as a national priority

Panel Speakers

- Dr. Paul Deitz
  - Director of the Human Research & Engineering Directorate, U.S. Army Research Laboratory
- Dr. John Doyle
  - John G Braun Professor of Control & Dynamical Systems, Electrical Engineering and BioEngineering, California Institute of Technology
- Dr. Will Leland
  - Chief Scientist, Network Systems Research Lab, Telcordia
- Dr. Eve Marder
  - Chair, Biology Department, Brandeis University
- Dr. Edward Perkins
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